

**WHAT IS CLAIMED IS:**

1. A method of implementing random early detection of congestion for a data packet queue, the method comprising:

storing at least one configurable segment-based drop probability profile associated

5 with the queue, each segment of the profile having a drop probability associated with a  
range of average queue sizes;

receiving an average queue size  $AQS$  for the queue;

determining whether the average queue size  $AQS$  falls within one of  $N$  segments  $S_i$ ,

$0 \leq i < N$ , corresponding to the drop probability profile associated with the queue; and

basing a drop/no-drop decision, for a data packet associated with the queue, on the

drop probability associated with a segment  $S_i$  when  $AQS$  falls within that segment.

The method of claim 1, wherein each data packet is assigned a drop priority from among

$M$  possible drop priorities,  $M > 1$ , and wherein  $M$  drop probability profiles are associated

with the queue, further comprising identifying, based on the drop priority of the data

packet awaiting the drop/no-drop decision, which of the  $M$  drop probability profiles to

in determining whether the average queue size  $AQS$  falls within one of  $N$  segments  $S_i$ .

3. The method of claim 2, wherein each of the  $M$  profiles comprises a high threshold  $T_H$  and

a delta threshold  $T_\delta$ .

4. The method of claim 1, wherein the configurable drop probability profile comprises a

high threshold  $T_H$  and a delta threshold  $T_\delta$ .

25 5. The method of claim 4, wherein  $AOS$  falls within  $S_i$  when

$$\begin{aligned} T_H - T_\delta / 2^i &\leq AQS < T_H - T_\delta / 2^{i+1} & i \neq N-1 \\ T_H - T_\delta / 2^i &\leq AQS < T_H & i = N-1 \end{aligned}$$

6. The method of claim 1, wherein the segment endpoints for each segment  $S_i$  are stored with the profile.

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7. The method of claim 1, wherein a set of drop probabilities  $P_i$  correspond respectively to the segments  $S_i$ , wherein basing a drop/no-drop decision comprises, when  $AQS$  falls within  $S_i$ , performing a random trial having two outcomes, *drop* and *admit*, where the probability of the outcome *drop* is approximately  $P_i$ .

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8. The method of claim 1, wherein multiple drop probability profiles exist, and wherein one set of drop probabilities  $P_i$  correspond to all profiles.

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9. The method of claim 1, wherein multiple drop probability profiles exist, and wherein a set of drop probabilities  $P_i$  is stored with each profile.

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10. The method of claim 1, wherein multiple drop probability profiles exist, and wherein each profile further comprises a segment type identifier, the segment type identifier corresponding to one of a plurality of fixed segment distributions.

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11. A method of implementing random early detection of congestion for multiple data packet queues, the method comprising:

maintaining a pool of drop probability profiles, the number of profiles in the pool less than the number of queues;

associating each of the data packet queues with at least one drop probability profile selected from the pool; and

when a drop/no-drop decision is to be made for a data packet destined for a particular queue, using the profile associated with that queue to arrive at the drop/no-drop decision.

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12. The method of claim 11, wherein each profile in the profile pool comprises a high threshold  $T_H$  and a delta threshold  $T_\delta$ .

13. The method of claim 11, wherein using the profile associated with that queue comprises

10 determining whether the average queue size  $AQS$  for that queue falls within one of  $N$  segments  $S_i$ ,  $0 \leq i < N$ .

14. The method of claim 13, wherein  $AQS$  falls within  $S_i$  when

$$T_H - T_\delta / 2^i \leq AQS < T_H - T_\delta / 2^{i+1} \quad i \neq N-1$$
$$T_H - T_\delta / 2^i \leq AQS < T_H \quad i = N-1$$

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15. The method of claim 13, wherein the segment endpoints for each segment  $S_i$  are stored with the profile.

16. The method of claim 13, wherein a set of drop probabilities  $P_i$  correspond respectively to

20 the segments  $S_i$ , wherein using the profile associated with a queue further comprises, when  $AQS$  falls within  $S_i$ , performing a random trial having two outcomes, *drop* and *admit*, where the probability of the outcome *drop* is approximately  $P_i$ .

17. The method of claim 16, wherein one set of drop probabilities  $P_i$  correspond to all

profiles.

18. The method of claim 13, wherein a set of drop probabilities  $P_i$  is stored with each profile.

5 19. The method of claim 13, wherein each profile further comprises a segment type identifier, the segment type identifier corresponding to one of a plurality of fixed segment distributions.

20. The method of claim 11, wherein each data packet is assigned a drop priority from among

10  $M$  possible drop priorities, and wherein each data packet queue is associated with  $M$  drop probability profiles, wherein using the profile associated with that queue to arrive at the drop/no-drop decision comprises using the profile associated with that queue and the drop priority of that data packet.

15 21. An integrated circuit comprising:

    a profile register to store an array of segment-based drop probability profiles;  
    a profile matcher to accept a data packet queue identifier and select an active drop probability profile, from the array of drop probability profiles, that is associated with the data packet queue identifier;

20     a segment selector to accept an average queue size  $AQS$  associated with the selected data packet queue and the active drop probability profile, the selector identifying the segment of the active profile within which  $AQS$  falls; and

25     a probability comparator to accept a drop probability corresponding to the segment identification from the segment selector, the comparator producing a random packet-drop signal with a probability approximately equal to the drop probability.

22. The circuit of claim 21, wherein the drop probability profile configuration of the profile register comprises a high threshold  $T_H$  and a delta threshold  $T_\delta$  for each entry in the array.

5 23. The circuit of claim 22, wherein the segment selector has the capability to identify the segment as one of  $N$  segments  $S_i$ ,  $0 \leq i < N$ , wherein the identified segment  $S_i$  is the segment for which

$$\begin{aligned} T_H - T_\delta / 2^i \leq AQS < T_H - T_\delta / 2^{i+1} & \quad i \neq N-1 \\ T_H - T_\delta / 2^i \leq AQS < T_H & \quad i = N-1 \end{aligned}$$

10 24. The circuit of claim 22, wherein the drop probability profile configuration of the profile register further comprises a set of drop probabilities, corresponding respectively to the possible segment identification values produced by the segment selector.

15 25. The circuit of claim 22, wherein the drop probability profile configuration of the profile register further comprises a set of segment endpoints.

20 26. The circuit of claim 22, wherein the drop probability profile configuration of the profile register further comprises a segment type identifier, the segment type identifier corresponding to one of a plurality of fixed segment types defined for the circuit.

27. The circuit of claim 21, wherein the profile matcher comprises a profile pointer register having at least one entry corresponding to each valid data packet queue identifier, the profile matcher selecting an active drop probability profile by returning a pointer associated with the data packet queue identifier.

28. The circuit of claim 27, wherein the profile matcher further accepts a drop priority identifier, and wherein, for each valid data packet queue identifier, the profile pointer register has one entry corresponding to each valid drop priority identifier, the profile matcher selecting an active drop probability profile b returning the register entry corresponding to the data packet queue identifier and the drop priority identifier.

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29. The circuit of claim 21, further comprising:

an average queue size register to store an array of average queue size elements  $AQS_i$ ,  
10 one element corresponding to each valid data packet queue identifier, and to supply the array element corresponding to the data packet queue identifier to the segment selector as  $AQS$ ; and

15 an average queue size filter to update an average queue size element  $AQS_i$  with a current queue size  $CQS_i$ , where both  $AQS_i$  and  $CQS_i$  are associated with a selected data packet queue.

30. The circuit of claim 29, wherein the filter operates according to the equation

$$AQS_i = AQS_i + \alpha(CQS_i - AQS_i),$$

where  $0 < \alpha < 1$ .

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31. The circuit of claim 30, wherein  $\alpha = 2^{-n}$ , where  $n$  is a positive integer.

32. The circuit of claim 21, further comprising a random number generator to generate random numbers for use by the probability comparator.

33. A packet routing device comprising:

a packet pipeline to receive and delay a packet;

a multiple-queue packet memory to receive a packet into the queue designated for that packet, when that packet reaches the end of the packet pipeline without being dropped;

5 and

a random early detection traffic conditioning circuit to snoop queue information from the packet while the packet is in the pipeline, the circuit having the capability to select a segment-based drop probability profile corresponding to the queue information and produce a packet drop/no-drop decision based on that profile before the packet reaches

10 the end of the pipeline.

34. The device of claim 33, wherein the packet pipeline has the capability to maintain the current queue size for each queue in the multiple-queue packet memory, and wherein the random early detection circuit uses the current queue size from the packet pipeline to maintain an average queue size for each queue in the multiple-queue packet memory.

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35. The device of claim 33, wherein the queue information corresponds to a destination port and a traffic class for the packet.

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36. The device of claim 33, wherein the random early detection circuit accepts a drop priority for the packet, and where the selection of a drop probability profile depends on the drop priority as well as on the destination port and traffic class of the packet.

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37. The device of claim 36, further comprising a traffic monitor circuit to produce the drop priority for the packet while the packet is in the packet pipeline.

38. The device of claim 33, wherein the random early detection circuit comprises a bank of user-configurable drop probability profiles and a user-configurable profile pointer register having at least one pointer, pointing to a drop probability profile from the bank, for each 5 queue in the multiple-queue packet memory, the random early detection circuit using the queue information to select a profile pointer from the register, thereby selecting the drop probability profile corresponding to the queue information.

39. The device of claim 33, further comprising multiple packet ingress interfaces, each 10 ingress interface coupled to supply packets to the packet pipeline.

40. An apparatus comprising a computer-readable medium containing computer instructions that, when executed, cause a processor or multiple communicating processors to perform a method for random early detection of congestion in a data packet queue, the method 15 comprising:

storing at least one configurable segment-based drop probability profile associated with the data packet queue, each segment of the profile having a drop probability associated with a range of average queue sizes;

receiving an average queue size  $AQS$  for the queue;

determining whether the average queue size  $AQS$  falls within one of  $N$  segments  $S_i$ ,  $0 \leq i < N$ , corresponding to the drop probability profile associated with the queue; and basing a drop/no-drop decision, for a data packet associated with the queue, on the drop probability associated with a segment  $S_i$  when  $AQS$  falls within that segment.

25 41. The apparatus of claim 40, wherein each data packet is assigned a drop priority from

among  $M$  possible drop priorities, and wherein  $M$  drop probability profiles are associated with the queue, further comprising identifying, based on the drop priority of the data packet awaiting the drop/no-drop decision, which of the  $M$  drop probability profiles to use in determining whether the average queue size  $AQS$  falls within one of  $N$  segments  $S_i$ .

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42. An apparatus comprising a computer-readable medium containing computer instructions that, when executed, cause a processor or multiple communicating processors to perform a method for random early detection of congestion in multiple data packet queues, the method comprising:

10 maintaining a pool of drop probability profiles, the number of profiles in the pool less than the number of queues;

15 dynamically associating each of the data packet queues with at least one drop probability profile selected from the pool; and

when a drop/no-drop decision is to be made for a data packet destined for a particular queue, using the profile associated with that queue to arrive at the drop/no-drop decision.

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